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DEVELOPMENT OF ELECTRON GUN WITH NON-INTERCEPTING GRIDS

Report No. 5
Contract No. DA 36-039 AMC-02270 (E)
DA Project No. IP6-22001-A-055-04

Fifth Quarterly Progress Report
28 May 1964 to 28 August 1964

U.S. Army Electronics Laboratories
Fort Monmouth, New Jersey

Microwave Electronics Corporation

3165 Porter Drive
Palo Alto, California

DEVELOPMENT OF ELECTRON GUN WITH NON-INTERCEPTING GRIDS

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Electronics Command Technical Requirement
No. SCL-5912, dated 24 September 1962

Fifth Quarterly Progress Report
28 May 1964 to 28 August 1964

Object

Conduct investigations leading to the development of an experimental electron gun with non-intercepting grids.

Prepared by

Marshall McDonald
Joseph Drees

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

PURPOSE

The purpose of this program is to conduct investigations leading to the development of experimental electron guns with non-intercepting grids.

The design objectives for the electron gun to be developed are as follows:

- Beam voltage, 25.0 kv, Min.
- Beam current, 10 amps, Min.
- Perveance, 2.5 microperveance
- Cut-off amplification factor, greater than 100 for 100 percent cut-off
- Area convergence, greater than 100 to 1
- Beam diameter, 0.1 inch, Approx. Min.
- Cathode loading factor, 2 amps/cm^2, Max.
- Control grid intercepting current, 0

ABSTRACT

During this reporting period, studies were conducted and tests performed covering the following categories:

- Operation of the 0.570-inch radius cathode, multi-electrode gun using hexagonal aligned grids in the beam tester showed substantial improvement in the beam profile over previous efforts. Beam diameter of approximately 0.110-inch was obtained. Grid interception was still far too high to be acceptable (30 to 40 percent at cathode current).

- A pair of aligned grids having 0.030-inch square openings and 0.002-inch wire width (88 percent open) was shown to be non-intercepting when operated with a 0.570-inch spherical radius cathode and a 0.375-inch spherical radius anode. Grid interception was below 1 percent of cathode current.

- A spherical anode (R = 0.295) was installed in place of the regular anode on the 0.570-inch radius cathode gun using hexagonal mesh aligned grids (83 percent open). Operation in the beam tester showed this pair of grids to be non-intercepting. Grid current on this system was also below 1 percent of cathode current.

- Additional pairs of aligned grids were made. Hexagonal mesh molybdenum grids were shown to be an improvement over square mesh. Deviation chart analysis of these grids showed alignment and spherical shape out beyond the necessary 0.960-inch diameter.

- Cathode heater fields were shown to affect the beam shape by increasing its diameter about 10 percent as was discussed in Quarterly Report 3. Operation in which the tube was pulsed at a time when the heater current was a maximum positive value showed that the beam profile was affected more by the resulting heater field than by the opposite polarity heater field. Beam

size appeared to be independent of heater field polarity, however. A double pancake bifilar-wound heater was used.

- Cathode heater fields were shown to influence grid interception when a spherical anode was spaced 2 to 3 times the optimum (concentric) distance from the cathode. One polarity (not defined) provided lower (5 percent) grid interception than that obtained from zero heater current operation. The opposite polarity resulted in much higher (25 percent) grid interception than that obtained from zero heater current operation. Variations in heater fields had no affect on grid interception when the spherical anode was located concentric with the cathode.

PUBLICATIONS, LECTURES, REPORTS AND CONFERENCES

There were no publications, lectures or reports resulting from research carried on under this contract during the period. One conference was held.

1. July 9, 1964 at Sylvania Electric Products, Mountain View, California.

   Participants:

   Lt. David Hallock, USAEL
   M. McDonald, Sylvania Electric Products
   A. Scott, Sylvania Electric Products

FACTUAL DATA

PART I. TESTS WITH THE M4 GUN (0.570 R CATHODE AND ALIGNED GRIDS)

The M4-gun parameters were the same as those used on M3, which was discussed in Quarterly Report 4. The new mounting arrangement shown in Fig. 1 and discussed in the last report was the only change from M3 to M4. The new arrangement permitted respacing of the gun elements by the simple process of changing one of the spacing washers. The cathode can be, and has been, readily replaced without disturbing the grid alignment on a pair of grids. In addition, the electrical leakage problems previously causing trouble were eliminated. Component parts of this gun are shown in Fig. 2.

One set of beam profiles obtained from the M4 gun having aligned grids, 0.570-inch radius cathode, multi-electrode and regular anode, is shown in Fig. 3. Microperveance was 1.9 for these profiles. Similar performance was achieved when the gun was operated at a microperveance of 2.0. Operating at microperveances lower than 1.9 still produced the same beam size but current distribution in the beam was not as good. Current distribution was typified by a triangular beam profile.

Under all test conditions the grid interception was far too high to be acceptable.

Beam profiles shown were obtained with the three elements of the multi-electrode connected to the cathode. Efforts to further improve the beam shape by applying suitable voltages to these elements were unsuccessful.

A comparison of gridded and ungridded beam profile is shown in Fig. 4.

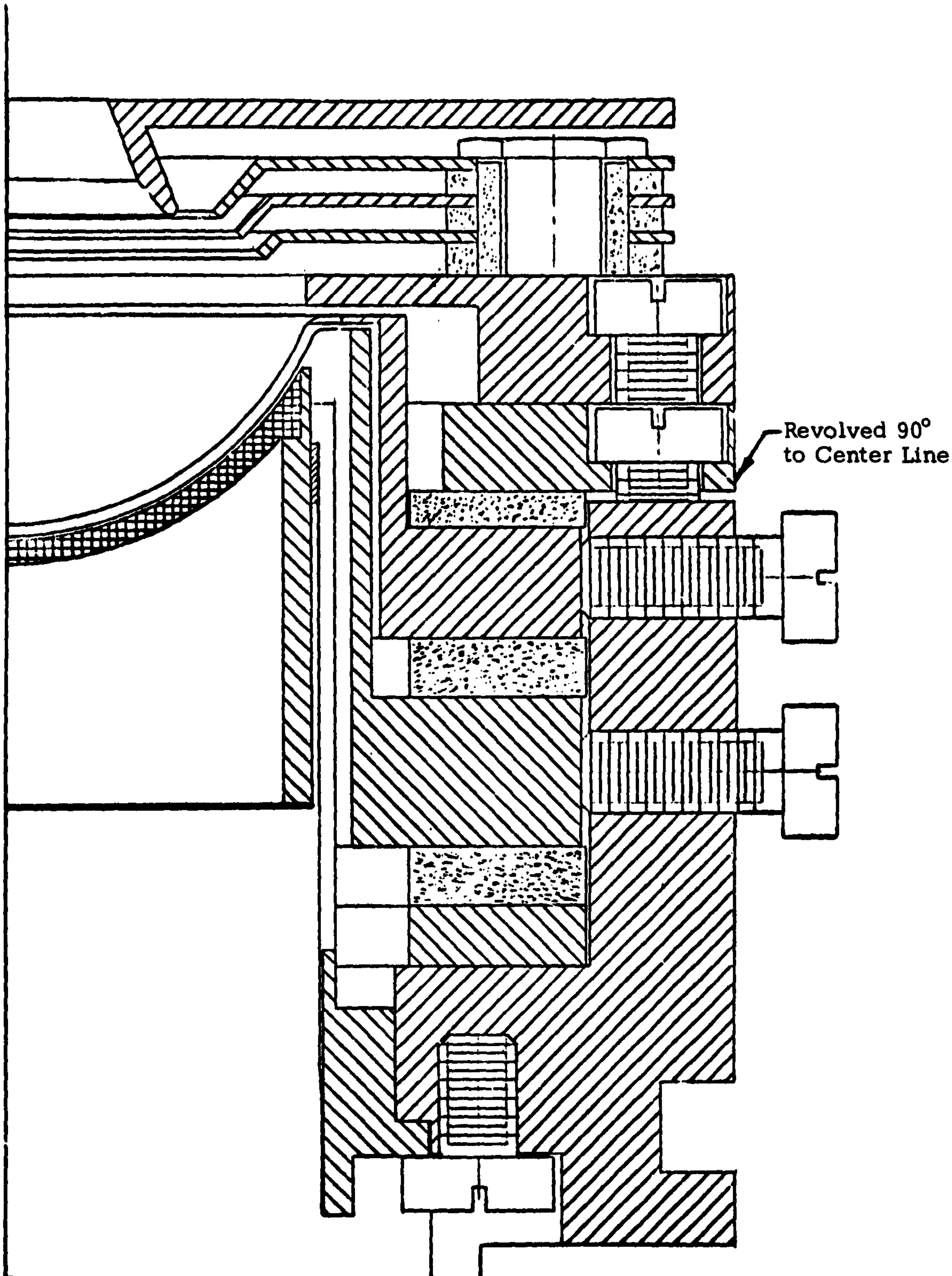


Fig. 1. M4 gun with aligned grids.

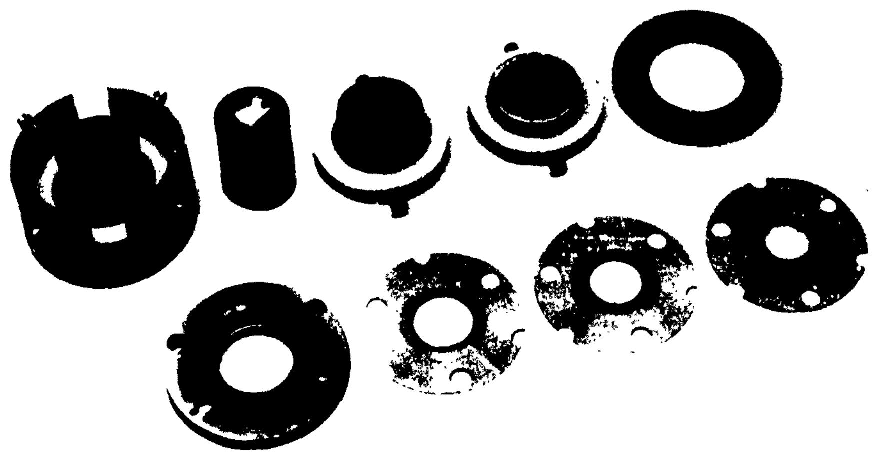
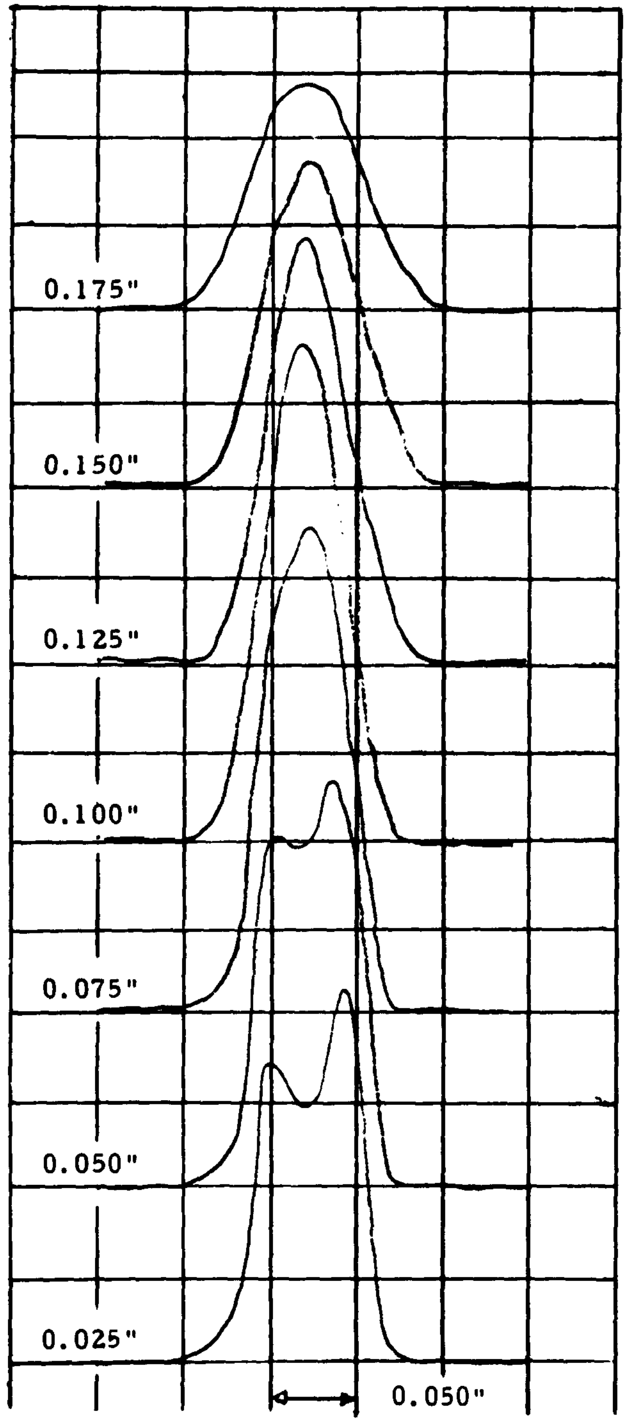


Fig. 2. Photograph of component parts, M4 gun.



Heater	125 Watts
Pressure	3×10^{-7}
Beam Voltage	2.5 kv
F_1 Tied to Cathode	
F_2 Tied to Cathode	
F_3 Tied to Cathode	
F_4 Tied to Cathode	
I Cathode	240 mA
I Grid	120 mA
E Grid	+20 v
M Perveance	1.9

Fig. 3. Beam formation, M4 gun, electrostatic.

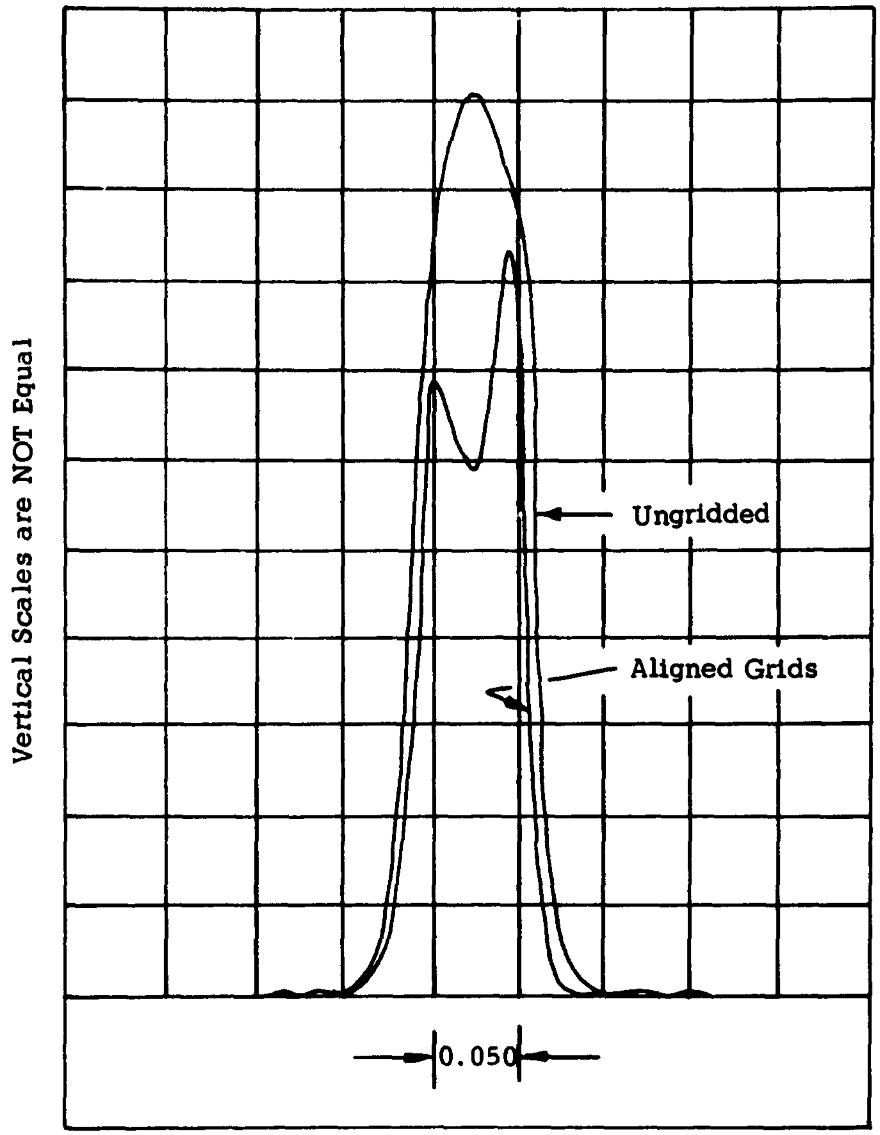


Fig. 4. Beam shape comparison, gridded and ungridded gun.

PART II. GRIDS

Two sets of aligned grids were mounted and used in tests during the time covered by this report. One set had 0.030-inch square openings with 0.002-inch wide wires and was mounted with the shadow grid directly on the cathode. The other set had hexagonal mesh of 0.020-inch across flats with 0.002-inch wide wires. It was mounted 0.004 to 0.006-inch off of the cathode. Both sets were drawn from photo-etched flat grids as detailed in previous reports. The former set of grids was mounted in an M3 gun configuration, except for a spherical anode and used to check grid interception as detailed later in this report. The hexagonal set of grids was mounted in an M4 gun configuration and tested as discussed in Part I of this report. A pair of grids made for M3-type grid mounting are shown in Fig. 5.

The hexagonal set of grids was inspected after installation and after operation in the beam tester by means of the deviation chart. Figure 6 shows the deviation chart for this set of grids after operating several hours in the gun tester.

The amount of deviation from the theoretical straight line is less than 0.002-inch at all points; the spherical shape continues out to a diameter of 0.960-inch. Spherical shape is required to a diameter of 0.955-inch as discussed in Quarterly Report 4.

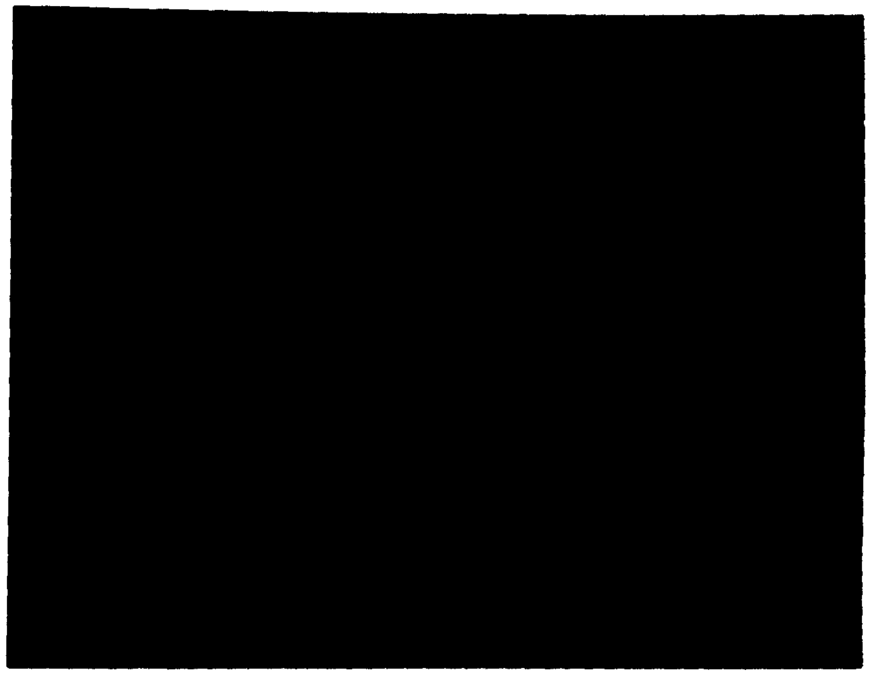


Fig. 5. Photograph of aligned grids, hexagonal mesh.

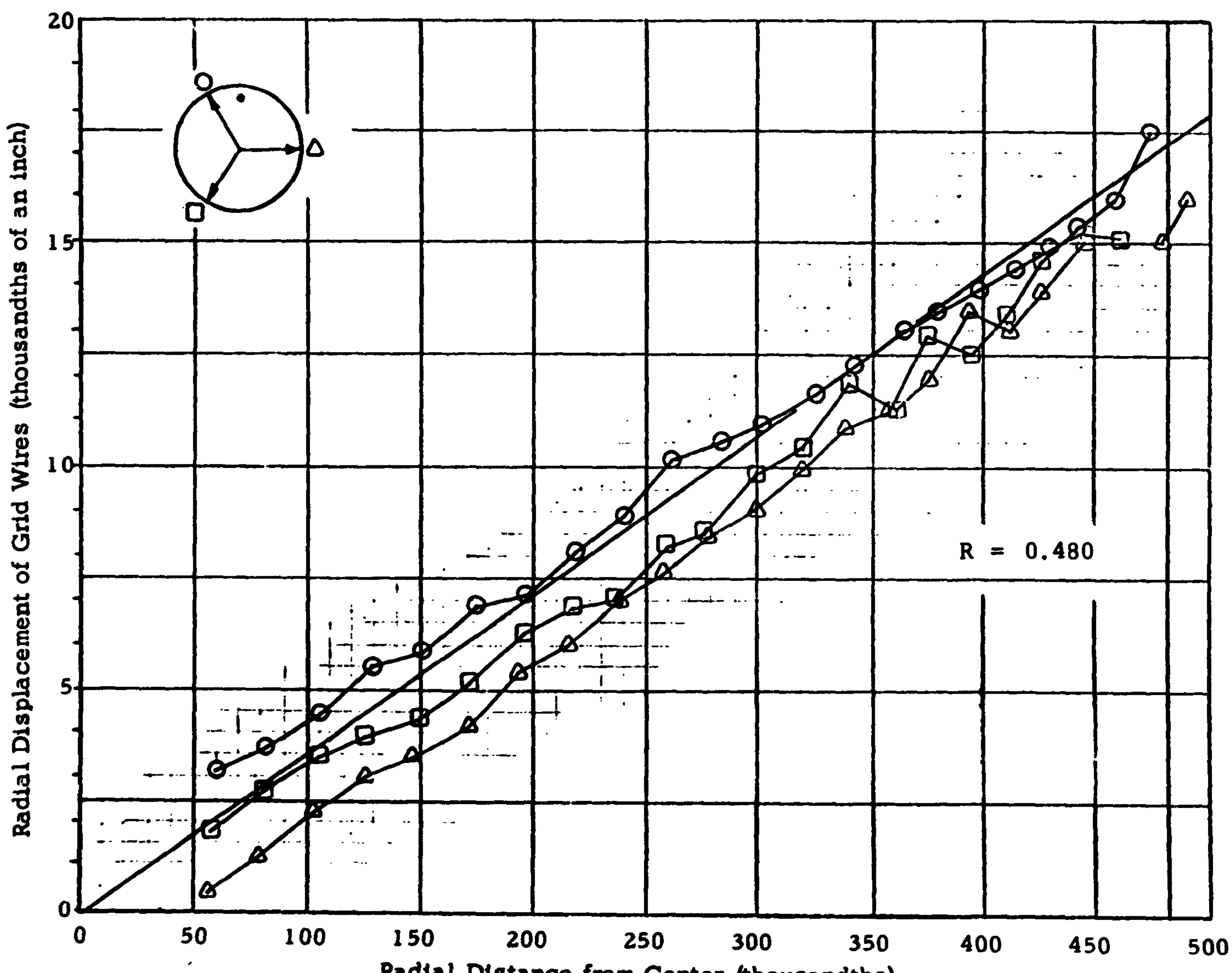


Fig. 6. Deviation chart, aligned grids, 0.020 hexagonal mesh, M4 gun after operation.

PART III. PROVING GRIDS NON-INTERCEPTIVE

Two sets of aligned grids were shown to be non-intercepting. This was achieved by using a spherical anode spaced some 0.200-inch from the grids. Two different systems were used.

One system consisted of a 0.570-R cathode, aligned grids and spherical anode installed in a demountable vacuum system, utilizing Vac Ion pumping. This system was essentially the same as that used in testing the spherical triode discussed in Quarterly Report 2. Figure 7 shows the configuration used. The shadow grid was mounted directly on the cathode and held in place by means of the thin molybdenum sleeve shown. Grids were 0.030-inch square mesh; wire width was 0.002-inch. Performance of this triode is shown in Figs. 8 and 9. When operating at 4 kv no perceptible grid current could be detected until the grid voltage reached a value of 5.0. At still higher voltages the grid current was remarkably small. Grid interception as a percentage of beam current was found to decrease with the higher beam voltages as shown in Fig. 10.

The second system, using a spherical anode, was installed in the beam tester, following successful operation of the first unit in the demountable vacuum system. This arrangement was designed to prove that the second pair of aligned grids would also function as a non-intercepting grid. Figure 11 shows the arrangement. The spherical anode was small enough to be placed inside the smallest of the multi-electrodes so that none of the focusing elements need be moved in order to use the spherical anode. This permitted testing as a triode without disturbing the grid alignment or grid-to-cathode spacing.

Previous operation of this gun produced a reasonably satisfactory beam, but grid interception was high. Typical grid current was 30 to 40 percent of cathode current. Figure 12 shows the results of operating as a triode, the very same cathode, aligned grids and focus electrodes with a spherical

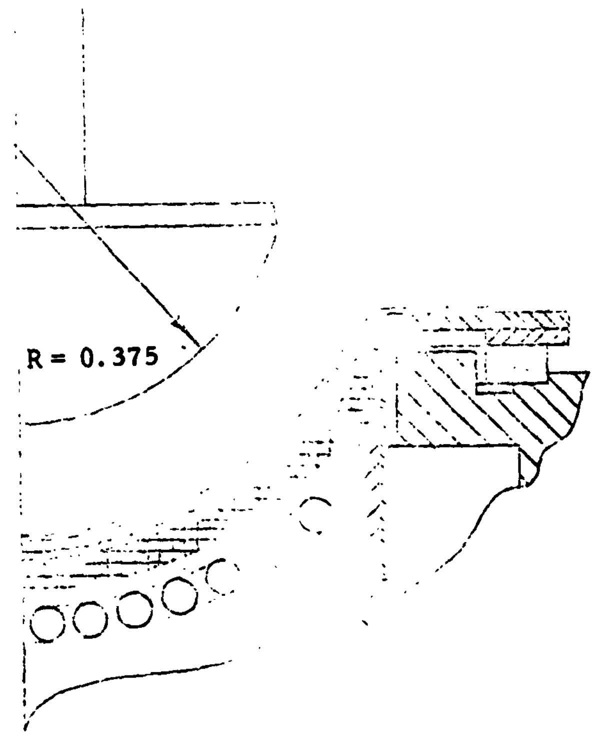


Fig. 7. M3 gun with spherical anode and 0.030 square mesh aligned grids.

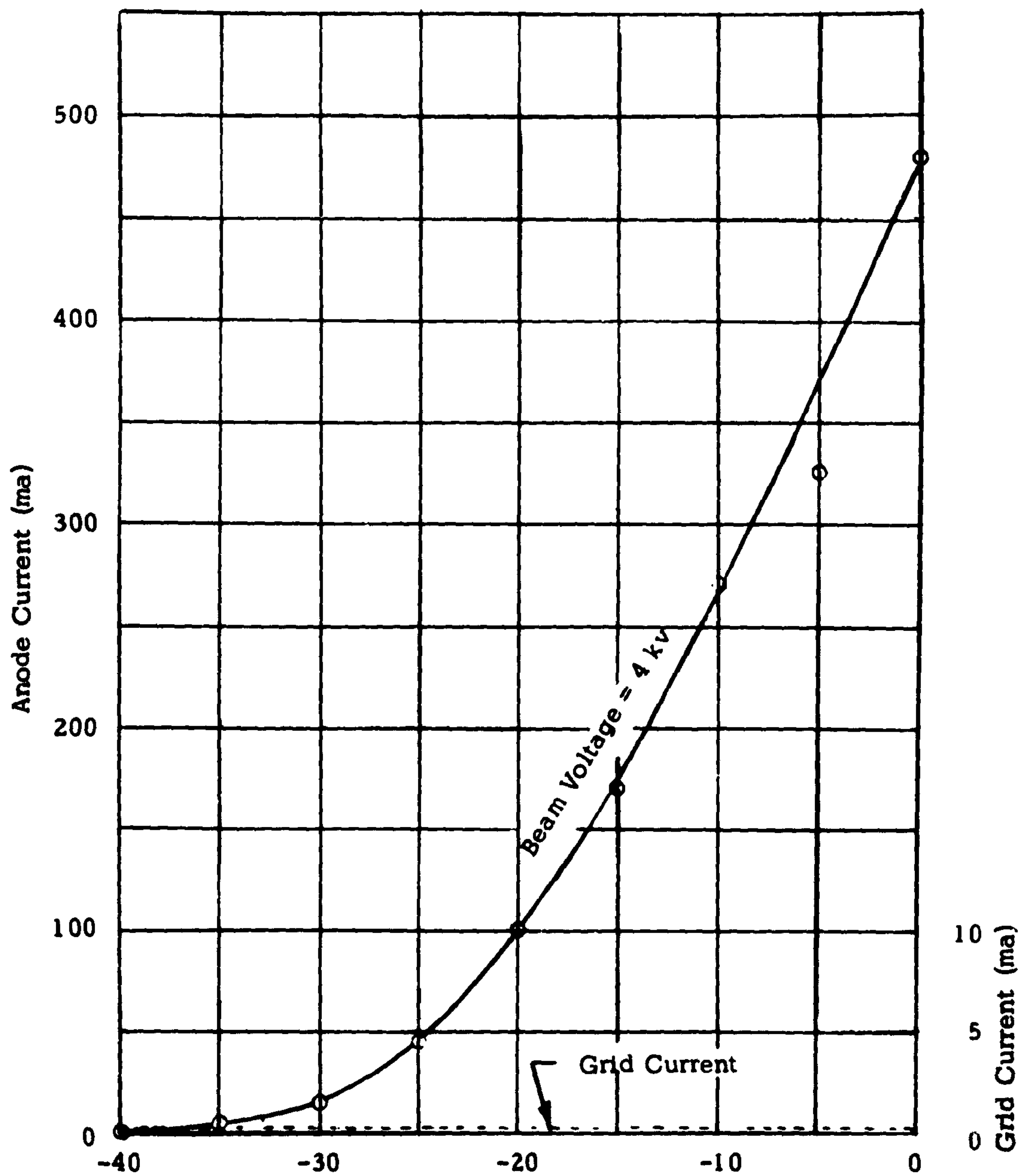


Fig. 8. Gun characteristics, M3 with aligned grids and spherical anode.

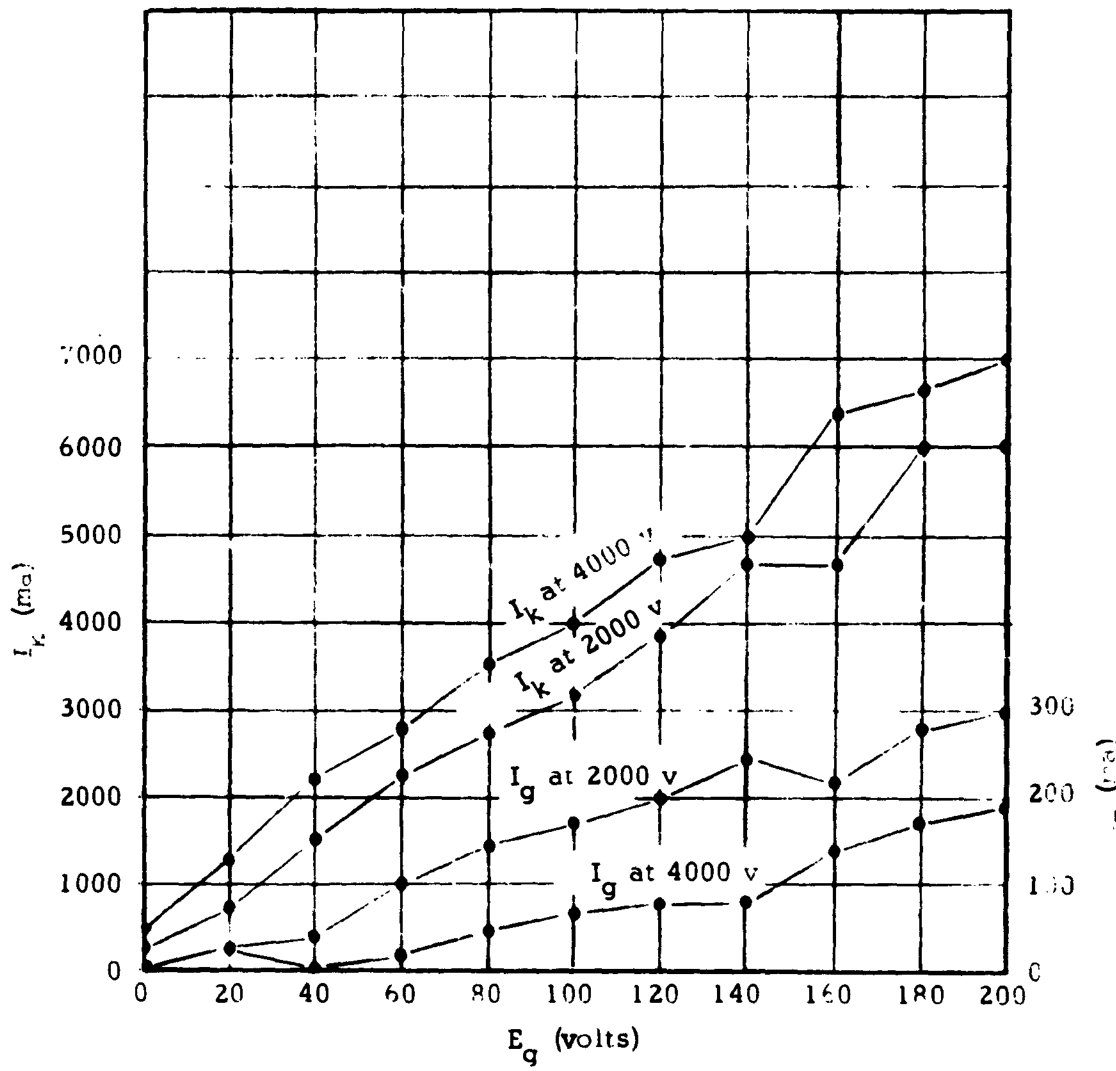


Fig. 9. Gun characteristics, M4 with aligned grids and spherical anode.

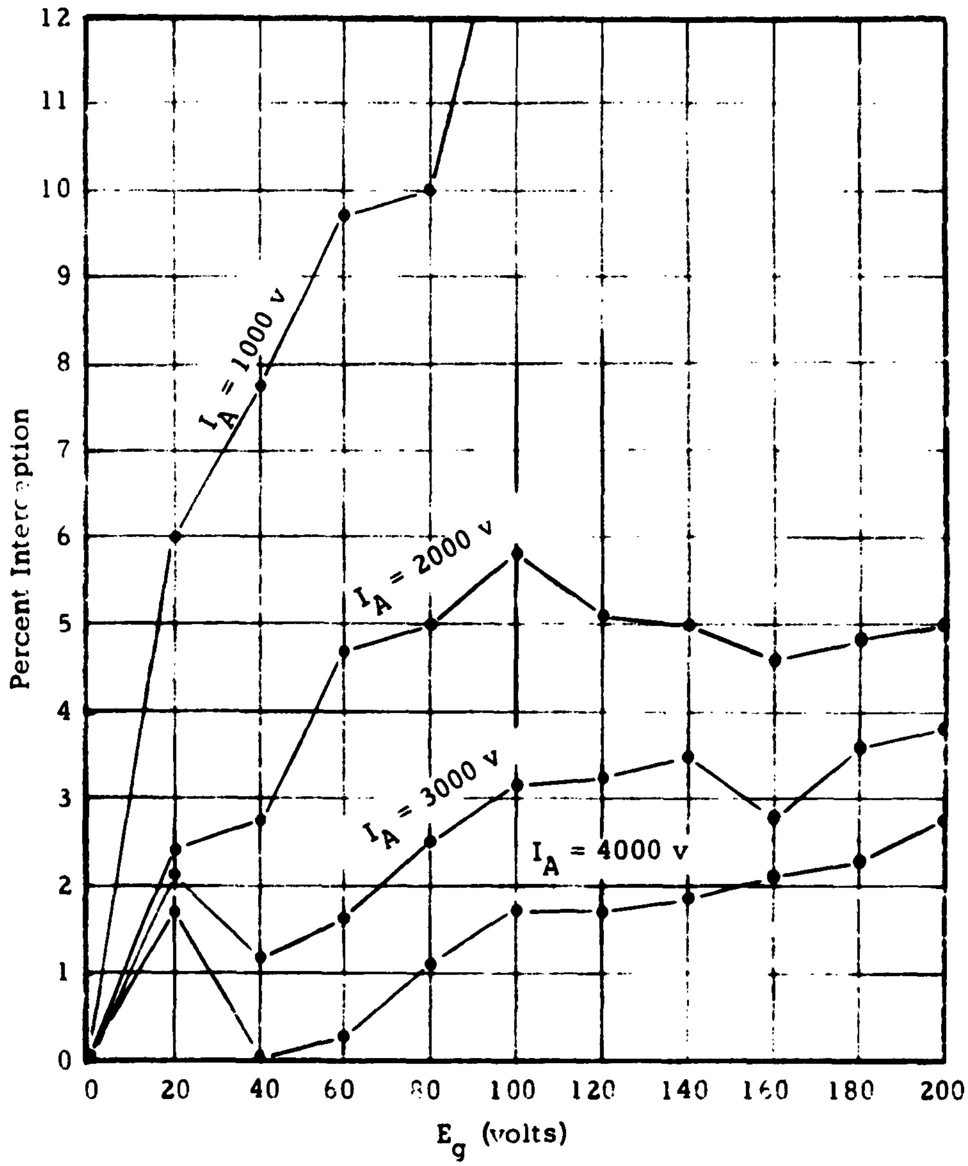


Fig. 10. Percentage interception M3 with spherical anode.

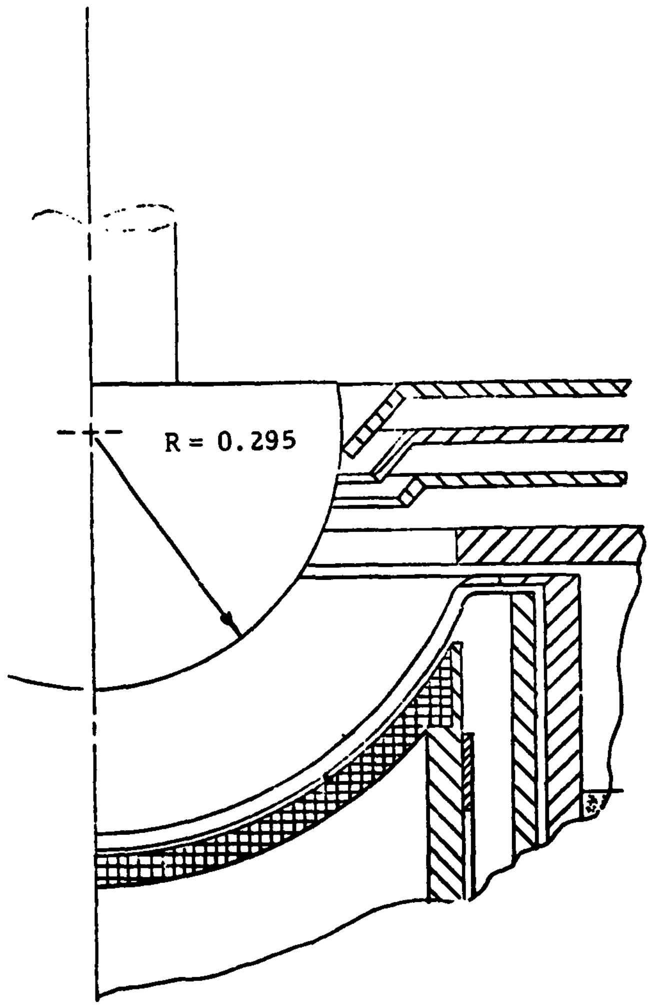


Fig. 11. M4 gun with spherical anode and 0.020 hexagonal mesh aligned grids.

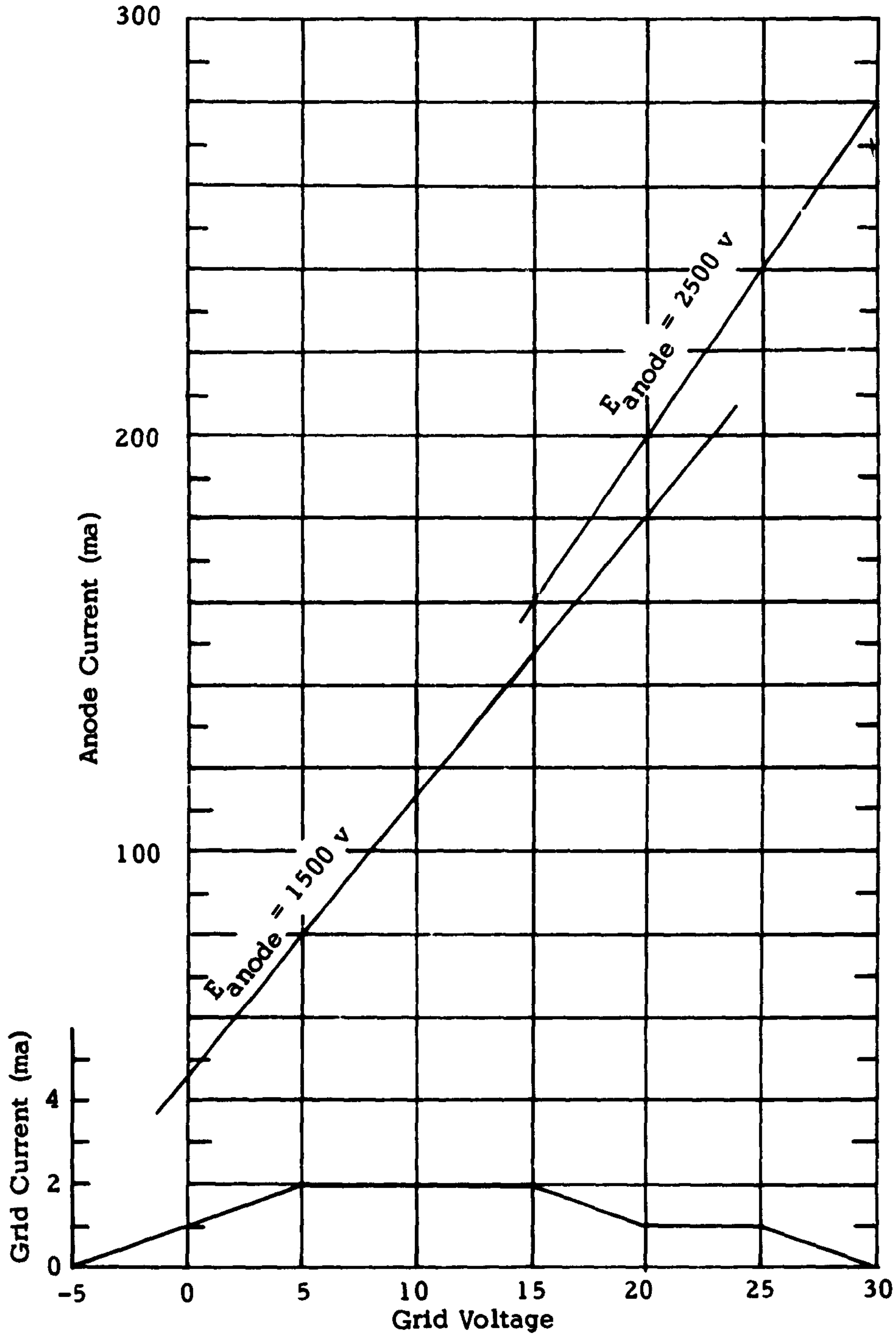


Fig. 12. M4 gun characteristics with aligned grids and spherical anode.

anode. When operated at 2.5 kv and a grid voltage +20 volts, or higher, the grid interception was 0.5 percent of cathode current or less. Grid current became so small as to be imperceptible at a grid voltage of +30 volts when operating at 2.5 kv.

After the 0.020-inch mesh hexagonal grids had been shown to operate with very low current interception, the spherical anode was repositioned further away from the grids. With the cathode-to-spherical anode distance increased by a factor of 2, (spacing of 0.400-inch) the grid system still operated as a non-intercepting grid. Only by increasing the spacing by a factor of 3 could the grid interception be increased to some 10 to 15 percent of cathode current. No position was found which would duplicate the high (30 to 40 percent) grid interception values encountered when operating as a grid-controlled gun using the regular anode.

Finally, the spherical anode was moved closer to the grid by a factor of approximately 2. No appreciable increase in grid interception took place and even with the spherical anode positioned 0.075-inch from the grid there was less than 1 percent of the cathode current intercepted by the grid.

PART IV. EFFECT OF FIELDS FROM CATHODE HEATER

The beam profiles obtained from operating the gun with the first hexagonal mesh grids were substantially improved over those shown for a dimensionally similar gun in Quarterly Report 4. This suggested that the effect of heater-current fields might now be ascertainable. Quarterly Report 3 discussed the effect of heater fields on the ungridded version of this gun with both electrostatic beam formation and magnetic focusing.

The same report showed wider beam profiles approximating a 10 percent increase in beam diameter as a result of heater fields. Because of this information, subsequent usage of the beam tester had been with the heater current phased to minimize the effect of heater fields. Specifically, the gun had been pulsed at zero heater current in order to eliminate or minimize the fields from the heater. This was accomplished by using a phase shifter ahead of the trigger generator. The phase shifter is essentially a 3600 rpm synchronous motor driving a two-lobed triggering element to produce 120 pulses per second. This is the optimum arrangement for pulsing the gun under test at zero heater current when the heater is supplied by 60-cycle ac power. However, it is not optimum for pulsing the tube at other times during the heater current cycle. Once the pulse is moved off the zero heater current position by operating the phase shifter, the heater current fields are alternately positive and negative. Because of this condition the effect of a small magnetic field from the heater in a particular direction could not be ascertained.

The phase shifter was changed to produce 60 pulses per second which permitted pulsing the gun undergoing test at times of maximum heater current in either a positive or a negative direction. Figure 13 shows the beam profiles that resulted from such operation of the 0.570-inch radius cathode, hexagonal mesh aligned grid gun. The reference profiles made at zero heater current represent two of the better profiles obtained for the aligned grid version of this gun to date. The heater was phased and the pin-hole moved from 0.050- to 0.100-inch, as shown, but no other change was made

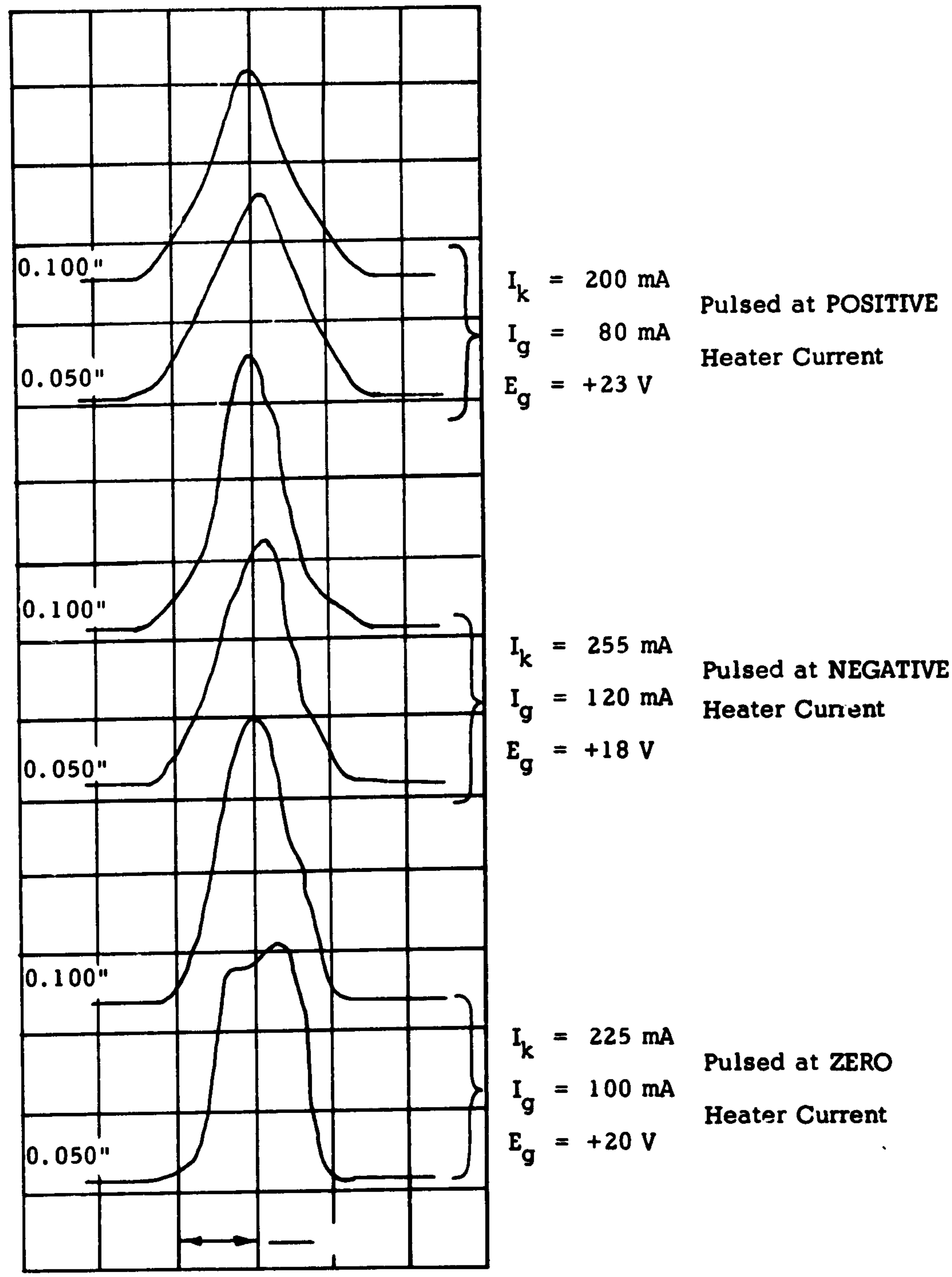


Fig. 13. Effect of phasing heater current on beam profile.

in obtaining the six profiles. All profiles were made consecutively within a period of some 30 minutes. Analysis of the profiles indicates that the increase in beam size attributable to heater fields is not a function of the direction of those fields; increase in beam size was obtained whether the heater fields were positive or negative.

Beam shape for the positive field was somewhat different from that obtained with the negative field, however. The heater used in this particular test was a double-pancake bifilar wound design specifically arranged to be non-inductive. Evidently the method of operation in which the heater current is zero at the time of pulsing the gun is appropriate for use until such time as additional developmental work on a heater suitable for non-phased operation is undertaken.

Further work on the effect of heater current fields was done after the installation of the 0.348-inch R spherical anode on the M4 gun in the beam tester. This was undertaken because the spherical anode provided a non-intercepting grid system and, thus, afforded the opportunity of ascertaining the effects of magnetic fields from the heater on the amount of grid interception. It should be clearly understood that heater phasing (i.e. pulsing the tube at specific points on the heater current cycle) had no perceptible effect on grid interception when the spherical anode was positioned concentrically with the cathode. When the spherical anode was moved away from the cathode to a distance of 0.400-inch, twice the optimum spacing, heater phasing changed the amount of current intercepted by the grid significantly. Figure 14 shows the change in grid interception when the heater current at the time of pulsing is as follows:

- zero heater current
- maximum heater current, positive direction
- maximum heater current, negative direction.

Some preliminary work, in which voltages were applied to the multi-electrode, suggested that the use of positive voltages at these points could be used to

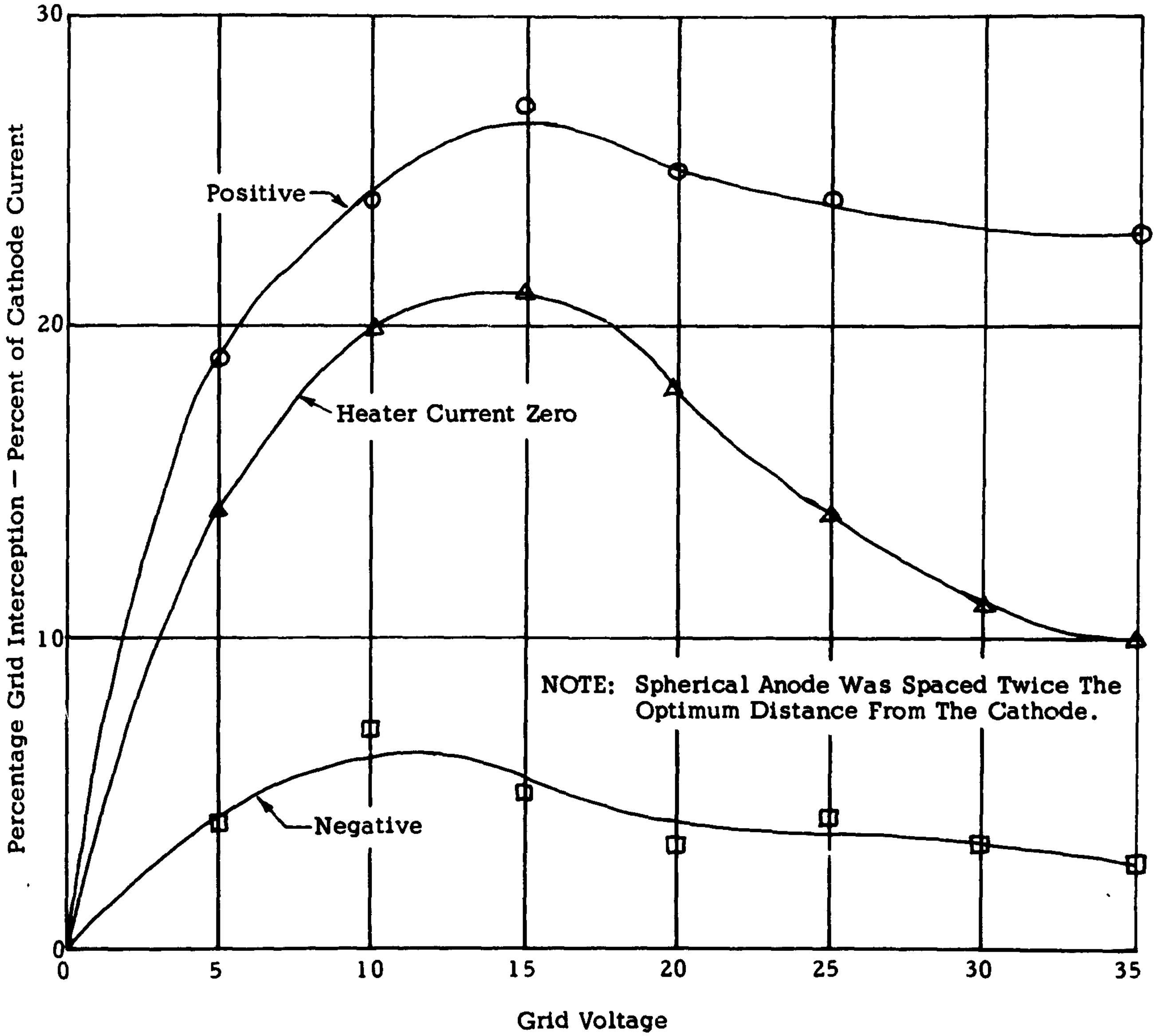


Fig. 14. Effect of phasing heater current on grid interception.

reduce the amount of grid interception. This was the spherical anode spaced 0.400-inch from the cathode.

CONCLUSIONS

Aligned grids with a 0.548-inch spherical radius and an included angle of 120° were shown to operate as non-intercepting grids in two different arrangements using spherical anodes. Interception was well below 1 percent of cathode current in both cases. Grid interception is not especially sensitive to the grid voltage applied to pulse the gun.

Changes in grid interception due to differential expansion of the grids were not encountered when using the spherical anodes. Evidently the high grid currents experienced on the gun tests are attributable to distortion of the equipotentials when the sphere is replaced by an anode with a large hole placed close to the cathode.

Mounting the shadow grid directly on the cathode or spaced a few thousandths of an inch away from the cathode yields equal results in terms of grid interception when tested with spherical anodes.

Cathode heater fields play a significant part in beam formation on a 0.570-inch radius cathode, high perveance gun when the heater is ac powered. The fields from cathode heater may also have a detrimental effect on grid interception.

A non-inductive heater design suitable for use in an aligned grid gun with a 1-inch cathode of about 0.570-inch spherical radius may pose some serious problems. For the present the design of such a heater will be treated as a subordinate problem and the practice of pulsing the gun under test at zero heater current will continue.

PROGRAM FOR NEXT INTERVAL

The two gun arrangements used in the beam tester and the two spherical anode arrangements will be duplicated in the tank. A detailed study will then be undertaken to ascertain any differences which might be responsible for the high grid interception.

The effect of applying a positive potential of about 1 volt to the shadow grid will be studied experimentally.

The tank study will undoubtedly lead to reshaping the grid, revising the anode, and/or changing the contour of the cathode. These changes will be made and proved out in the tank.

Following the tank study, changes needed in shape of grids, cathode or anode will be incorporated in the M4 configuration and studied further in the beam tester.

Once low grid interception, and satisfactory beam shape are attained in a gun it will be further tested in a magnetic field.

U.S. Army Electronics Materiel Agency, Fort Monmouth, New Jersey. Rpt No. 5. DEVELOPMENT OF AN ELECTRON GUN WITH NONINTERCEPTING GRIDS. Fifth Quarterly Progress Report, 28 May 64 to 28 August 64, 23 p. incl. illus.

Unclassified Report

Studies and tests were conducted during the fourth quarter covering the following catagories:

1. Deep cathode gun - Test results were obtained showing that a change in cathode shape or modified grid to cathode spacing will be required to obtain a satisfactory beam.
2. Grids - Two more sets of aligned grids were made representing additional steps toward a perfected production technique.
3. Cathode assembly - A nonbrazed mounting was developed for the cathode grid on the deep cathode gun permitting tests in which the grid is removed without damage to cathode.
4. Mounting structure for electron gun - A new gun structure was designed and built which permits changes in spacings of grid and cathode and grid to grid.

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2. Nonintercepting Grid

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